ENGINEERING PERSPECTIVE

CONTENTS

ENGINEERING PERSPECTIVE Volume: 3 Issue: 4 31 December 2023

e-ISSN: 2757-9077 Open Access

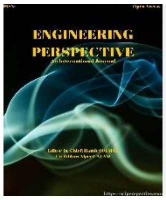
ENGINEERING PERSPECTIVE

An International Journal

Volume: 3 Issue: 4 31 December 2023

https://sciperspective.com

Engineering Perspective 3 (4): 57-62, 2023



e-ISSN:2757-9077

ENGINEERING PERSPECTIVE

https://sciperspective.com/ Research Paper

Study on the Flexible Dynamic Analysis of the Wheel Loader Under Working Conditions and Comparison with Static FEA Results

Sami Gökberk Biçer[1*], Mehmet Can Katmer[1,2]

[1]*Hidromek A.Ş., Ankara 06935, Turkey*
[2]*Graduate School of Natural and Applied Sciences, Gazi University, Ankara, 06500, Turkey*

ABSTRACT

The boom is the main body part of the mechanism for wheel loader earth-moving machines. It is critical that the boom is able to both meet the kinematic requirements and withstand the stresses that come from the breakout and lifting of the material during operation. Theoretical forces can be extracted from the mechanism after the completion of the kinematic modeling. The boom, which can be examined under static conditions with reference to these forces, can be evaluated within the framework of basic requirements. However, within the scope of this approach, it is not possible to determine the problems that may occur in the dynamic working conditions of the wheel loader. This may cause unexpected failure. For this reason, the boom design, which has met the requirements in terms of static strength, should also be reviewed dynamically. In this study, the kinematically designed boom part was first analyzed in the MSC Mentat package program in the most statically critical position. In order to be evaluated dynamically, the structure was modeled as flexible dynamics in the MSC Adams package program. In this way, stress-time distributions of the boom were obtained from data on working conditions. According to these results, the structure was also examined dynamically in terms of strength.

Keywords: Earth Moving Machinery; Finite Element Method; Flexible Dynamic Analysis; Wheel Loader

History
Received: 03.08.2023
Accepted: 19.11.2023

Author Contacts
**Corresponding Author*
e-mail addresses : gokberk.bicer@hidromek.com.tr, mehmet.katmer@hidromek.com.tr

How to cite this paper: Biçer, S.A., Katmer, M.C., (2023). Study on the Flexible Dynamic Analysis of the Wheel Loader Study on the Flexible Dynamic Analysis of the Wheel Loader. Engineering Perspective, 3 (4), 57-62. http://dx.doi.org/10.29228/eng.pers.72736

1. Introduction

Construction machinery has become indispensable in the understanding of modern industry, as it contains the conveniences that human labor cannot provide (in many areas such as job security and economics, especially in sustainability). Both the incomparable increase in the amount of work done per unit of time and the decrease in the need for raw materials to be spent during this period constitute a critical basis for the construction machinery to be an irreplaceable part of most sectors. The workload that construction machines are expected to handle is also increasing significantly. In this context, the increase in the variety of machines developed specifically for the task performed is a natural output of the process. Excavators, motor graders, compactors, wheel loaders, and backhoe loaders are the form of the basis of generally accepted construction machinery.

Wheel loader construction equipment can be used in many different sectors such as mine sites, construction sites, demolition sites, garbage separation, and waste areas. Each field has different usage requirements compared to each other. Although the usage areas vary, the basic working conditions undertaken by the wheel loaders are breakout, loading, and lifting operations. In general, these use cases also occur as a successive cycle. For this reason, generalizing the use over a single cycle will not be the wrong approach for wheel loaders. However, since wheel loaders can perform the loading cycle in many different work areas, it is necessary to consider these difficult conditions. In some places, it is expected to lift a single and large marble mass, while in some places it is expected to work with fine and/or coarse-grained sand, gravel, or soil materials. What is expected from wheel loaders is to meet all these requirements. Studies on force calculations and optimization of the loader mechanism have been published by Pavlovic J [1].

The operation also called the usage cycle, which involves breakout, loading, lifting and then dumping respectively, constitutes a work sequence for the wheel loader. Alleyne A. G. carried out studies on the movement conditions of the mechanism in the creation of loading models for the powertrains in construction machines [2]. It can perform this process with a mechanism that works connected to its main body and is driven by a hydraulic system. The loader mechanism generally consists of 5 basic parts. These are the boom that forms the main body of the mechanism, the z-bar that provides the diagonal transmission of the bucket movement, the linkage that acts as the transmitter, the bucket that provides the transport and loading of the material, and the cylinders that drive the whole system. The kinematic and dynamic simulation studies for the loader construction equipment z-bar part were carried out by Janosevic D [3].

The boom accommodates all other working parts due to the setup of the mechanism. For this reason, it is the basic element that meets all the loads that the construction machine is exposed to due to field conditions and transmits it to the main body. It is critical to meet the structural strength criteria in the design of the boom, as it acts as the main carrier and transmitter in the wheel loader usage cycle. Worley M. D.'s simplified dynamic model design study for boom design has been published [4]. Studies on the optimum design of the loader boom mechanism were carried out by Yu Y., Shen L., and Li M. [5]. Zhang Z. and He B. carried out studies on the optimum and adaptive design of wheel loader construction machines [6].

In this study, the boundary conditions to which the boom design is exposed were determined and input was created for both static and flexible dynamic analysis. The strength performance of the design was reviewed within the framework of the determined boundary conditions.

2. Material and Methods

The stages of determining the boundary conditions covering the working conditions of the boom model, whose kinematic and 3D design has been completed, are shared under the title of materials and methods. The diagram showing the workflow within the scope of materials and methods is shared below. The steps for the study were carried out over the shared flow (Figure 1).

Figure 1. Material and method workflow

2.1 Calculation of Theoretical Force Values

Calculation of wheel loader boom mechanism force values constitute the basic inputs for both static and flexible dynamic analysis processes. For this reason, it is critical to calculate the force capacities by the free-body diagram of the design. A free-body diagram of the mechanism is shared below (Figure 2).

In the creation of the free body diagram, the distances of all connection points as well as the freedom of movement and rotation should be considered. In addition, the 5 basic components that create the skeleton of the mechanism should be considered as rigid. The free-body diagram of the mechanism fixed to the main body from A, B, and C points is shared in Figure 2. Research on mechanism calculations in loaders is also mentioned in the study of spatial kinematic modeling and simulation of wheel loaders. Li Y. performed and analyzed matrix analyses of the mechanism using MSC Adams in kinematic analysis [7]. In the mechanism design, the power source is a hydraulic drive. Since the power comes from hydraulics, mechanism optimization also affects the fuel consumption of the construction equipment. To ensure minimum power consumption, the analysis and calculations of the kinematic design were carried out by Shin K. in the mechanism optimization study [8]. The kinematic setup is the main factor in the calculation of the load values. The force ranges that the cylinders can apply are used to determine the theoretical capacity of the system. In the loader boom optimization study, the force calculations for a wheel loader mechanism are mentioned. In this study published by Kolte S, the mechanism capacities were revealed over the cylinder values [9].

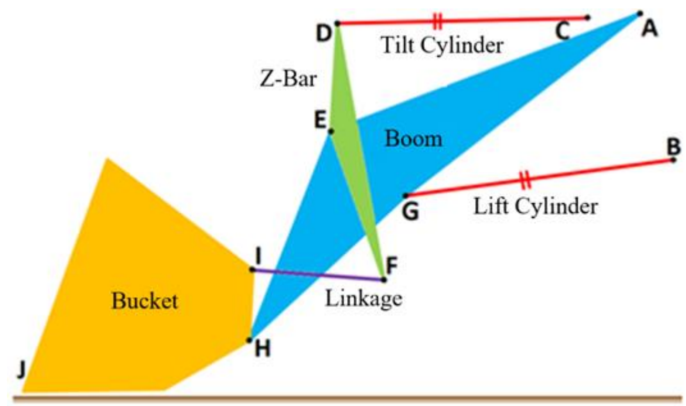


Figure 2. Free body diagram

Wheel loaders have critical positions determined by standards. Breakout position which is focused on the maximum hydraulic force capacity for material and critical tipping load which is the determination of wheel loader stability are the most important of these. The position known as the material force is called the breakout force in literature. Technical information for this force is determined by the ISO 14397-2 standard [10].

The part numbering highlighted in the relevant standard is named the lift cylinder, safety chain, axle support center, force measuring device, pulley, and ground plane respectively. The breakout force value, which must be calculated by the standard, is also important for boom strength evaluation. Theoretically, the highest force on the structure is determined by this value. The basic approach is based on the fact that the total moment and force values are 0 due to the static balance [11]. Static calculation formulas used for force values are shared below.

$$\sum_{i=1}^{n} M = F_1*D_1+F_2*D_2+\ldots F_n*D_n=0 \quad (1)$$

$$\sum_{i=1}^{n} F_{x,i}=0 \quad (2)$$

$$\sum_{i=1}^{n} F_{y,i}=0 \quad (3)$$

In addition to the breakout force, the machine tipping load value is also critical. In this position, the force value is calculated at the furthest load center reach, considering the balance condition of the machine. With this calculation, the safe load value that the building can carry after breaking the material is determined. The ISO 14397-1 standard is binding for wheel loaders' balance position lifting capacity. Static calculations were carried out by taking into account the overturning criteria in the mechanism kinematic diagram, which was brought to the appropriate position according to the standard requirements. Detailed descriptions of the calculation steps are taken from the relevant standard [12].

2.2 Static Analysis with Finite Element Method

The first step in evaluating the boom design in terms of strength is to perform static analysis using the finite element method under critical load boundary conditions according to referenced standards. With the calculation of the theoretical force data, the boundary conditions that form the basis of the static analysis inputs are also completed. The finite element method is based on dividing a 3D design into small mathematical equations and solving it with matrix definitions. The smallest structure that is divided and converted into the mathematical matrix is called an element. This process is called meshing the 3D data and is performed in the MSC Apex package program. Mesh quality affects the effectiveness of the finite element analysis directly. On the one hand, the use of the mesh with poor element quality negatively affects the accuracy of the solution results, on the other hand, obtaining extremely good element quality unnecessarily prolongs the solution time. Considering this situation, the most appropriate element size and quality determination was performed for the relevant design. In the mesh step, the HEX8 element type was used because it has better performance in getting consistent results and contributes to obtaining the optimum solution time. In addition, since only boom strength values will be examined in this study, linear bar elements were preferred instead of cubic mesh elements in z-bar, link, bucket, and cylinder elements. In this way, both the kinematic structure of the mechanism was preserved, and the use of elements was concentrated on the boom. The model, the mesh step of which was completed, was transferred to the Marc package program to perform analyses with the finite element method. Defining the kinematic degrees of freedom correctly in the finite element model is one of the most important issues in the analysis. The loader mechanism is designed to have only freedom for rotation at all connection points known as a revolute joint. Rigid mathematical equations named RBE'2 is preferred in FEA works so that the freedoms can be defined accurately.

RBE'2 approach is based on combining selected connection nodes with rigid mathematical equations at a central node. In this way, the motion kinematics in the relevant axis is provided. The schematic image for the related definitions is shared below (Figure 3).

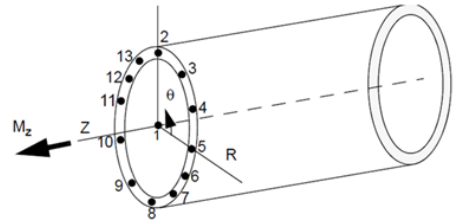


Figure 3. RBE'2 connection schematics

Construction machines are exposed to high stresses from place to place throughout their lifetime. This raises certain requirements in both the kinematic and structural design phases. The mechanism that meets the requirements in terms of kinematics must have sufficient strength to withstand the forces structurally. To meet high stress values with elastic material behavior, S355J2C-N steel is generally used in the construction machinery industry. S355J2C-N steel was taken as a reference in this study, which was carried out to examine the boom design. The mechanical properties of the relevant structural steel are shared in detail in the table below (Table 1). The data of the TS-EN 10025-2 standard is taken as a reference in the mechanical properties of steel.

Table 1. Material properties of S355J2C-N [13]

Young's modulus (GPa)	210
Poisson's ratio	0.3
Yield Strength (MPa)	355
Elongation (%)	22

The analysis model, whose boundary conditions, material data, and kinematic freedoms were defined, was analyzed statically by using the finite element method by both the ISO 14391-1 standard and the ISO 14391-2 standard.

2.3 Flexible Dynamic Analysis

When the field working conditions of wheel loaders are reviewed, it is seen that the general structure is heavily influenced by dynamic conditions. Dynamic conditions arise from both the operation of the boom mechanism and the machine traveling. In this study, the effects of the boom mechanism were evaluated. It is not possible to obtain time-dependent stress maps for operating conditions in the design, whose analyses are performed for only static FEA under critical positions. With the flexible dynamic analysis performed in the MSC Adams package program, both the boom time-stress map and the dynamic effects caused by the mass inertia were examined. In this way, it is aimed to determine the stress distributions that may be overlooked in static boom stresses. The steps to be followed to perform the flexible dynamic analysis are shared below (Figure 4). While applying these steps, definitions were made by making use of the field data of the wheel loader.

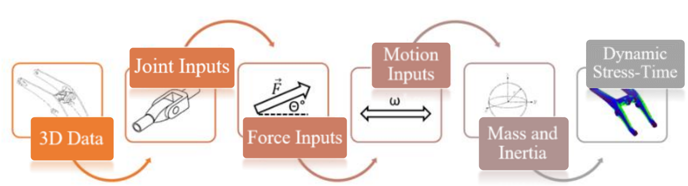


Figure 4. Flexible dynamic analysis stages

One of the most important issues to be considered during the verification phase of a design is to determine the conditions of use by the field data. In this way, the analysis boundary conditions can be defined by the field conditions and according to the results, if needed, design changes will be made with a correct progression. The working loop cycle of the wheel loader front arm mechanism can be evaluated through 4 main movements. These movements are breakout, loading, lifting, and dumping. For these stages, it was also taken as a reference in the study of examining the front mechanism kinematics of loader construction machines in the combined mechanism methodology [14]. In addition, in the study examining the structural improvement methods of loader construction equipment with static and dynamic measurements, the mentioned cycle stages were taken into consideration [15]. The detailed schematic image of the mechanism is shared below (Figure 5). The numbers on the image represent the breakout, loading, lifting, and dumping positions, respectively.

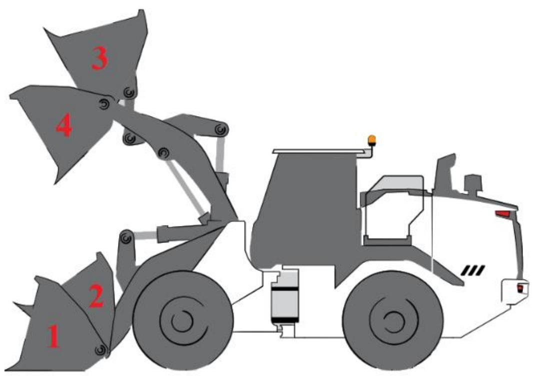


Figure 5. Mechanism movement stages

Solid models, whose mechanism design was completed, were transferred to the MSC Adams program. Since the flexible dynamic analysis is performed on the boom, simplifications have been made without changing the kinematic design. In the boom design, on the other hand, the main design was adhered to accurately determine the stress concentrations.

All the joints are designed to have only rotational freedom in the kinematic model. The correct definition of these joints in the Adams model is critical for force and moment transfer. For this reason, joints are defined by adhering to the free body diagram. Afterwards, the force values, which were calculated by ISO 14397-1 and ISO 14397-2 standards, were integrated into the 4-stage loading cycle. Drive inputs are provided to both the lifting and tilting cylinders for loading movements. It aims to accurately describe the dynamic effects of the mechanism by using machine field data in the categorization of cylinder movements. At this stage, considering the motion setup, the cylinder drives, and force inputs are formulated based on time. In the formulation approach, the Step5 function embedded in the MSC Adams program was used. This approach provides a quintuple polynomial approximation to the Heaviside step function. There are continuous first and second derivatives. Its third derivative is discontinuous at x=x0 and x=x1. The visual of the formulation input parameters is shared below (Table 2). The equation input data is entered in the format STEP5(x, x0, h0, x1, h1). Since the soft dynamic analysis is performed in the time domain, x data is defined as time.

Table 2. Step5 formulation input parameters

X	Independent variable
X0	X-axis start variable
X1	X-axis ending variable
H0	H axis start variable
H1	H-axis ending variable

When STEP5(time, 1, 0, 2, 1) is defined as the reference input, an output in the format shared below is received (Figure 6).

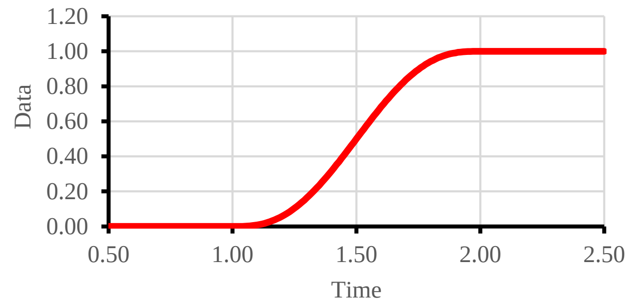


Figure 6. STEP5 formulation output graph

Both cylinder motion and force data are defined in the MSC Adams program using the STEP5 function. Images of the relevant entries are shared below in order (Figures 7 & 8).

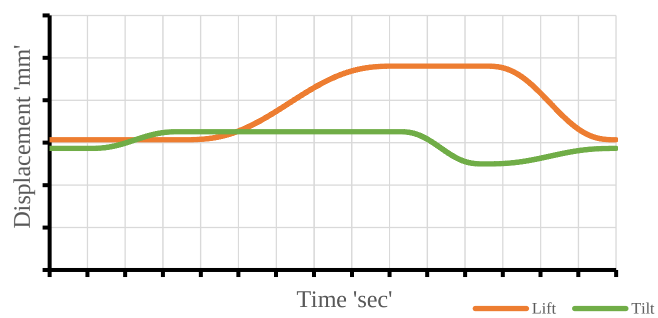


Figure 7. Motion input data for cylinders

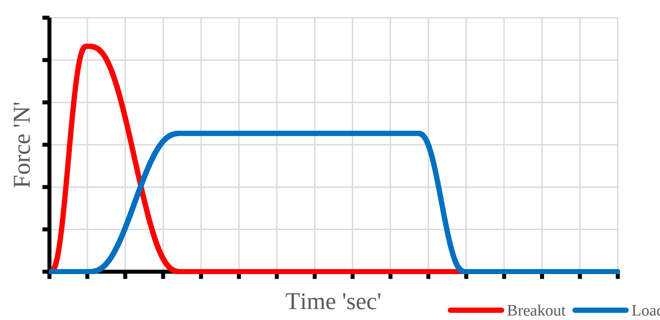


Figure 8. Force input data for condition steps

After defining the force and motion inputs, the mass and inertia information obtained from the 3D design program were transferred to the MSC Adams program. Then, the flexible dynamic analysis was solved in the MSC Adams package program.

3. Comparison of the Analysis Results

The evaluation of the stresses obtained with the static analysis outputs alone is not sufficient for the systems that are to be examined dynamically in the operating condition. While stress distributions can be obtained only for a selected moment with static conditions, stress maps can be obtained depending on the time in flexible dynamic analyses. In this way, the results can be examined over a determined cycle, and design changes can be made if needed. Wheel loaders work in dynamic conditions in the field. For this reason, examining the mechanism parts only under static conditions is not sufficient in terms of strength evaluations. The most important reason for this difference is that while the strength results of a stationary model under certain boundary conditions are obtained in static conditions, mass inertia is also involved in dynamic analysis. This difference was also obtained in the wheel loader boom examination. Stress distributions for static and dynamic analysis results are shared below with Von Mises theorem (Figures 9 & 10). Effects of the dynamic loading on the boom are clearly seen compared to static FEA results.

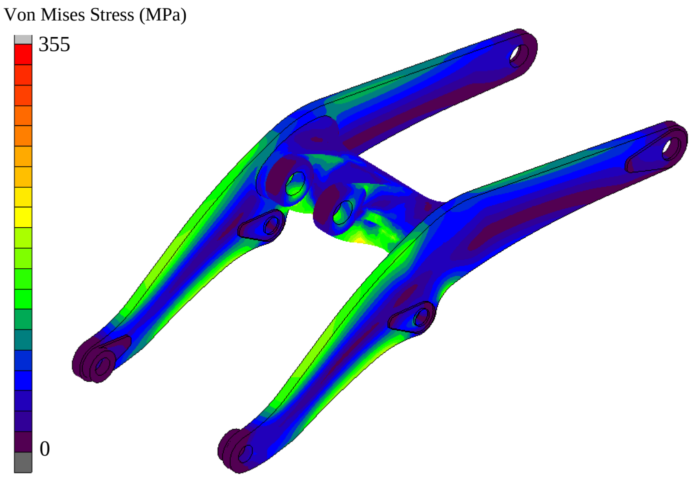


Figure 9. Static analysis stress distribution for breakout condition

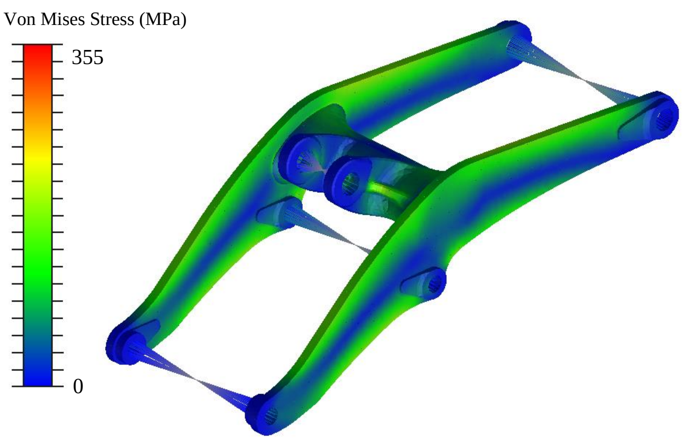


Figure 10. Dynamic analysis stress distribution for breakout condition

Flexible dynamic analyses performed by the working conditions to obtain time-dependent stress distributions play an important role in determining the possible critical stress distributions and concentration that may occur on the parts within the cycle time. The stress distributions obtained for each loading cycle stage of the boom design, which is analyzed as flexible dynamic according to the working cycle, are shared with the Von Mises stress theorem. Images are listed for breaking (I), loading (II), lifting (III), and dumping (IV) steps, respectively (Figure 11).

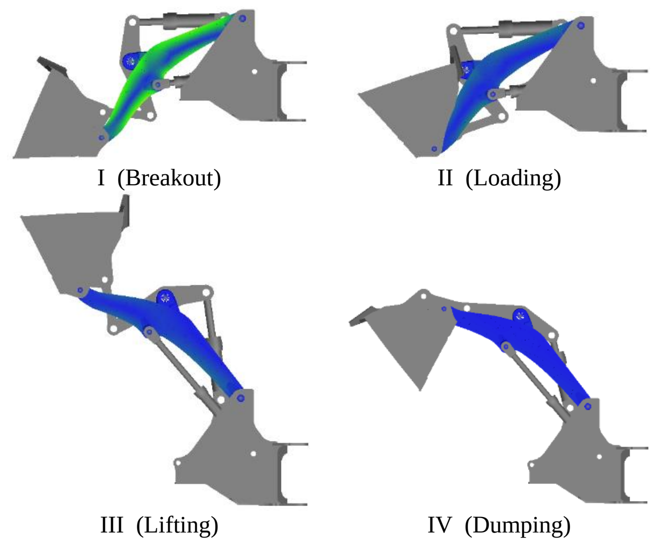


Figure 11. Flexible dynamic stress distribution according to steps

4. Conclusions

In wheel loader earth-moving machinery, the boom mechanism is the main part that is exposed to dynamic loads due to field working conditions. In this study, the force values of the boom mechanism, which is kinematic and 3D design has been completed, were calculated according to ISO 14397-1 and ISO 14397-2 standards. Then, static analyses were carried out with the finite element method in the MSC Marc program by the standard positions of the design. To determine the effects of the dynamic effects on the structure on the stresses, the dynamic analysis model was prepared in the MSC Adams program by utilizing the field data. The boom 3D design data has been added to the analysis as a flexible dynamic due to the evaluation of the strength. First, the static and dynamic analysis stress distributions were compared to each other for the positions specified by the standard. Then the flexible dynamic analysis outputs are examined for a specified cycle for the wheel loader.

When the data obtained as a result of the studies carried out are evaluated;

- For the earth-moving machines that are heavily exposed to dynamic loading, stress results obtained from static FEA provide an initial idea about the strength of the design.
- Determining the inputs for dynamic data as a result of field working conditions and performing dynamic analyses accordingly is a more accurate method for interpreting dynamic conditions.

Acknowledgment

This study has been published with the support of the Hidromek company. The authors would like to thank the Hidromek.

Nomenclature

FEA	Finite element analysis
Fx	X-axis component of the referenced force (N)
Fy	Y-axis component of the referenced force (N)
M	Total moment of the system (N.mm)
$RBE'2$	Multi-Point constraints element used in FEA

Conflict of Interest Statement

The authors declare that there is no conflict of interest in the study.

CRediT Author Statement

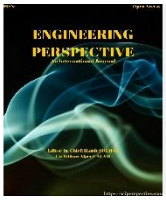
Gökberk Biçer: Conceptualization, Methodology, Supervision, Software, Writing – original draft

Mehmet Can Katmer: Conceptualization, Supervision, Writing – original draft

References

1. Pavlovic, J., Janosevic, D., & Jovanovic, V. (2018). Optimization of a Loader Mechanism on the Basis of the Directed Digging Force. Iranian Journal Science and Technology, Transaction of Mechanical Engineering, 43, 753-762.
2. Carter, D., & Alleyne, A. G. (2003). Load Modelling and Emulation for an Earthmoving Vehicle Powertrain. American Control Conference, 6.
3. Janosevic, D., Pavlovic, J., Jovanovic, V., & Predrag, M. (2014). Kinematic and Dynamic Simulation of the Wheel Loaders with the Z-Bar Working Mechanism. Research & Development in Heavy Machinery, 20(2).
4. Worley, M. D., & La Saponara, V. (2008). A Simplified Dynamic Model for Front End Loader Design. Journal of Mechanical Engineering Science, 2231-2249.
5. Yu, Y., Shen, L., & Li, M. (2010). Optimum Design of Working Device of Wheel Loader. International Conference on Mechanic Automation and Control Engineering, 461-465.
6. Zhang, Z., & He, B. (2018). Comprehensive Optimum and Adaptable Design Methodology for the Working Mechanism of a Wheel Loader. The International Journal of Advanced Manufacturing Technology, 94(4), 2095-3095.
7. Li, Y. (2013). Spatial Kinematics Modelling and Simulation of Wheel Loader. Columbia International Publishing Journal of Modeling, Simulation, Identification and Control, 1(2), 78-88.
8. Shin, K., Lee, S., Shin, H., Yoo, Y., & Kim, J. (2012). Coupled Linkage System Optimization for Minimum Power Consumption. Journal of Mechanical Science and Technology, 26(2), 1099-1106.
9. Kolte, S. S., & Makasare, P. A. (2015). Optimization of Loader Arm of Wheel Loading Shovel. International Journal of Engineering Research & Technology, 4(4), 1095-1099.
10. ISO 14397-2: 2007. Test Method for Measuring Breakout Forces and Lift Capacity to Maximum Lift Height.
11. Katmer, M. C., & Biçer, G. (2022). Z-Bar Design and Structural Analysis in Loader Construction Equipment. Orclever Proceedings of Research and Development, 1(1) 120-129. https://doi.org/10.56038/oprd.v1i1.147
12. ISO 14397-1: 2007. EMM Loaders and Backhoe Loaders Calculation of Rated Operating Capacity and Test Method for Verifying Calculation Tipping Load.
13. TS EN 10025-2: 2005. Hot Rolled Products of Steel Delivery Conditions of Nonalloy Steels.
14. Li, Y., & Frimpong, S. (2015). Compound Mechanism Modeling of Wheel Loader Front-End Kinematics for Advance Engineering Simulation. The International Journal of Advanced Manufacturing Technology, 78, 341-349.
15. Choung, J., Kim, G., Jang, Y., Choe, I., & Heo, M. (2004). Study on the Structural Analysis Method of Wheel Loaders Based on Static and Dynamic Measurements. ASME IMECE, 59486, 709-714.

Engineering Perspective 3 (4): 63-67, 2023



e-ISSN:2757-9077

ENGINEERING PERSPECTIVE

https://sciperspective.com/ Research Paper

Effect of Clutch Pedal Distances on Fuel Consumption Under Actual Operating Conditions

Hüseyin Bayrakçeken[1], Hicri Yavuz[2*], Turan Alp Arslan[1]

[1] *Department of Automotive Engineering, Faculty of Technology, Afyon Kocatepe University, Afyon, 03200, Turkey*

[2] *Department of Engine Vehicles and Transportation Technology, Afyon Vocational School, Afyon Kocatepe University, Afyon, 03200, Turkey*

ABSTRACT

Clutch systems are the auxiliary system for transmitting the power and torque obtained in the internal combustion engine to the gearbox, starting the vehicle, and providing gear changes. The different use of the clutch pedal directly affects the performance and fuel consumption of the vehicle. Research on fuel economy, performance, etc., in vehicles, is costly and time-consuming. In the studies conducted by researchers on braking and gearbox, experimental test equipment that allows the vehicle to operate in many different parameters and instantaneously control fuel consumption has been used. The studies have generally focused on braking and gearbox-related studies. This study investigates fuel consumption values at different pressing distances of the clutch pedal. In the experiments, with the engine at a constant speed of 3000 1/min and the gearbox in second gear, the fuel consumption at 0-20-40-60% depressions of the clutch pedal were measured. According to the data, fuel consumption values increased with increased clutch pedal depressing distance.

Keywords: Clutch; Fuel consumption; Pedal distance; Vehicle tester; Vehicle.

History
Received: 27.06.2023
Accepted: 08.10.2023

Author Contacts
**Corresponding Author*
e-mail addresses : *hicriyavuz@aku.edu.tr*, *bceken@aku.edu.tr*, *talparslan@aku.edu.tr*

How to cite this paper: Bayrakçeken, H., Yavuz, H., Arslan, T.A., (2023). Effect of Clutch Pedal Distances on Fuel Consumption Under Actual Operating Conditions. Engineering Perspective, 3 (4), 63-67. http://dx.doi.org/10.29228/eng.pers.72460

1. Introduction

In vehicles, different systems such as clutch and gearbox are combined to transmit the power and torque obtained from the internal combustion engine to the wheels. Depending on the operating conditions, the movement obtained from the engine may not need to be continuously transmitted to the gearbox. The vehicle may need to stop and change speed to a lower or higher. The clutch systems between the engine and the gearbox transmit or interrupt the movement obtained from the engine. In clutch systems, which play an essential role in transmitting power and torque, when the clutch pedal is not pressed, the clutch disk engages with the flywheel surface, and the movement in the engine is transmitted to the gearbox. When the clutch pedal is pressed, the engagement is interrupted, and the movement from the engine is not transmitted to the gearbox. This working principle of the clutch system also gives the driver the flexibility to shift gears to reach the desired speed or torque values. Clutch systems are found in vehicles such as cars, vans, trucks, and tractors. Clutch systems used in automatic transmission systems, torque converters, and hydraulic controlled clutch systems are also essential systems that provide an environment for the efficient operation of vehicles and provide high performance and fuel economy with appropriate torque.

Whether in passenger cars or commercial vehicles, the torque from the internal combustion engine is transmitted to the gearbox by the clutch system [1]. The working principle of the mechanical clutch is based on the principle that a pad with a high coefficient of friction compresses and transmits motion to the disk that can make an axial movement with the flywheel. The engine's torque is transferred to the gearbox and from there to the wheels with the effect of the circumferential friction force on the pad. Mechanical clutches are preferred over hydraulic clutches due to their ease of manufacturing and maintenance [2]. Therefore, the clutch system acts as an interface between the engine and the vehicle. When the vehicle is in motion, the engine provides power and torque at a certain speed. In this process, slip time is critical for the clutch system. Engine and gearbox speeds are variable due to the driver effect.

During the vehicle's take-off, the driver influences all dynamics, such as the clutch and accelerator pedal [3]. This effect has made the clutch, in particular, an essential part of the proper functioning of the powertrain. The clutch system interrupts or engages the power flow during gear changes. Thanks to this system, a smoother gearshift is achieved, and wear on the gearbox is minimized [4]. The clutch is in a constant state of energy transfer when synchronizing between the engine and the gearbox. In slip, it absorbs the prime mover energy and inertial energy [5]. The primary function of the clutch system, which is located between the engine and the gearbox, is to allow gear changes. At the same time, the vehicle is in motion to transfer engine torque to the driveline and to reduce irregularities by minimizing torsional vibrations caused by the engine. They are responsible for equalizing gearbox output speeds by regulating torque flow [6,7].

Dry-type clutches are popular in the transmission systems of small and medium-sized vehicles and parallel hybrid vehicles' engine clutch systems [8]. In the automotive industry, single or double dry clutches are widely used for low fuel consumption, reduction of pollutant emissions, reliability, and efficiency [9]. Although these types of clutches have many vehicle perspectives, the most critical share is in automobiles. The expected task of a dry clutch is to transfer the torque from the engine to the vehicle wheels. The engine torque is transferred to the gearbox main shaft and then to the wheels through friction and contact between the pressure plate and flywheel. Like brake pads, a high coefficient of friction is an essential phenomenon in clutch pads. Under normal operating conditions, kinetic energy generates high temperatures with friction [10].

Figure 1 shows the components of the clutch system. Here A is the clutch lining, B is the flywheel, and C is the clutch disk. Figure 1 (a) shows a complete picture of the clutch system. Figure 1 (b) shows the clutch engagement when the clutch pedal is not depressed, while Figure 1 (c) shows the moment of separation of the clutch disc and the clutch lining when the clutch pedal is depressed.

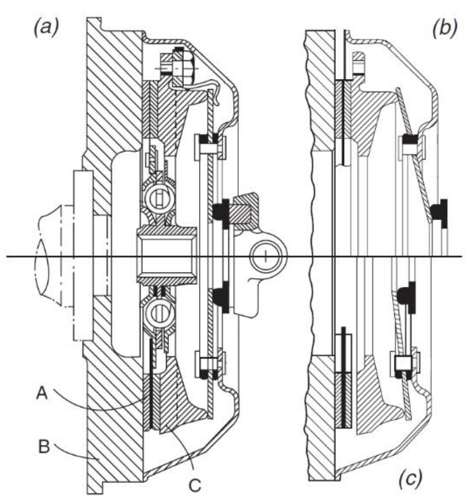


Figure 1. Schematic view of clutch system elements [11]

Improper torque distribution can lead to increased engine fuel consumption and emissions [12]. Research has been carried out in the automotive sector in recent years to improve driving and fuel efficiency. The power obtained in the engine is transmitted to the wheels by the drivetrain. The drivetrain is also very effective in the performance and fuel economy of the vehicle. Reducing fuel consumption and improving driving comfort is extremely important when developing new technologies. Trying every innovation and development in the industry without validation leads to high costs. In addition, this approach could be better for companies and researchers [13].

The braking phenomenon in vehicles can be continuous on a downhill descent or push-and-pull manner, depending on the traffic flow. Some drivers continue to press the accelerator pedal as traffic approaches an obstacle and then press the pedal hard [14]. Fuel savings of up to 27% can be achieved by the driver making gear changes under optimum conditions [15]. The clutch system is an essential system for vehicle control. Although the studies conducted by researchers have focused on braking or gearbox, they have not focused on the results related to clutch systems and fuel consumption. Fuel consumption, which directly impacts environmental problems and the economy, also exhibits a highly variable situation in clutch use. For optimum vehicle operation, the clutch pedal should be fully depressed, and the driver should take his/her foot off the clutch pedal. In this study, the fuel consumption of the clutch system in different pedal pressing distances other than optimum use in the vehicle test device in the laboratory environment was measured, and the results were compared.

2. Material Method

In the studies conducted by researchers, there are essential studies on tests related to vehicles. However, considering the high cost of road tests and the deviations that may occur in the test results, it is seen that precise measurements cannot be made. With the test device, different road conditions can be created in the laboratory environment, and tests can be performed in a standardized and precise manner [16]. Test platforms have advantages compared to on-road test drives in that they are cheaper to operate, easier to perform tests, repeatable, and can be fully automated [17]. The vehicle test device on which the experiments are carried out and the performance tests can create road conditions in the laboratory environment. Although there are many studies in this field in the literature, it is understood that studies have been carried out with simulation methods and road tests. However, not all conditions can be fulfilled in simulation tests. In addition, the cost of road tests is high, and the sensitivity of the experimental results is relatively low. The device in which the experiments were carried out was created by considering all these factors. The road conditions were created in the laboratory environment, and the standard tests were created to be more sensitive [16]. Technical specifications of the test device are given in Table 1.

Table 1. Test device technical specifications

Engine Volume	1.4 L
Number of Cylinders	4
Fuel Type	Gasoline
Maximum Power of the Engine	57 kW
Maximum Torque of the Engine	115 Nm
Gearbox Type	Manual 5 gears forward 1 reverse
Clutch Type	Dry type single clutch

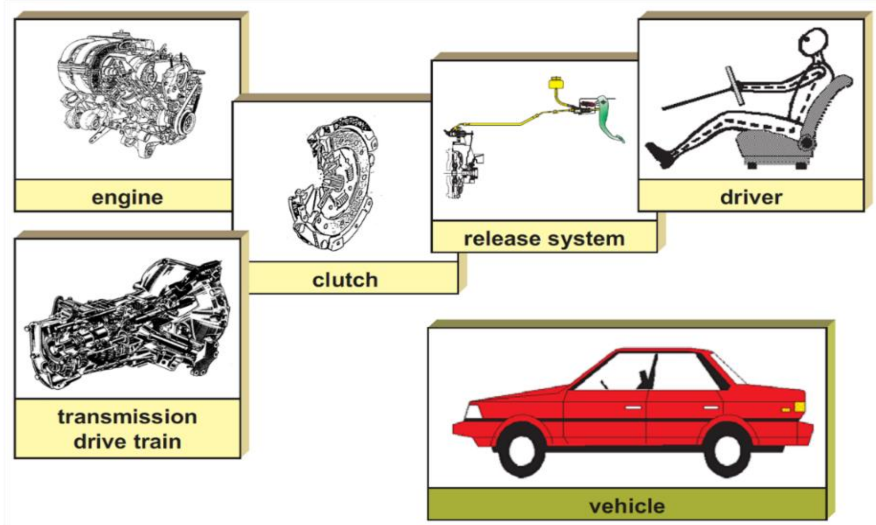


Figure 2. Clutch system representation in a vehicle [18]

Figure 2 represents the parameters related to the clutch during driving. The driver requires the use of the clutch system in situations such as gear changes or neutralization. The clutch pedal is pressed by the driver when such a need arises. When the clutch pedal is pressed, the mechanical or hydraulic system elements in between provide a pushing movement on the clutch ball. With this pushing movement, the clutch release plate removes the pressure on the clutch disk and allows the movement coming from the engine to leave the gearbox. With this motion transmission, gear neutralization or gear change operations can be performed.

Depending on the driver, different pedal pressing distances occur in using the clutch pedal during vehicle operation. Some drivers, such as drivers who are just learning to drive or tired drivers, for example, when waiting at a red light, apply continuous pressing force on the clutch pedal while the vehicle is in gear instead of shifting into neutral.

In addition, the clutch pedal is depressed at different distances to ensure that the vehicle takes off in the frictional effect that occurs when the flywheel and clutch lining is engaged during vehicle start-up. These different uses of the clutch pedal may cause differences in fuel consumption. This study aims to determine the changes in fuel consumption depending on the use of the clutch pedal. The schematic picture of the test rig is shown in Figure 3. Instantaneous fuel consumption can be measured precisely in the test device. The experiments were carried out by determining the fuel consumption at 0-20-40-60% clutch pedal distances where the engine can continue to run at 3000 1/min in second gear.

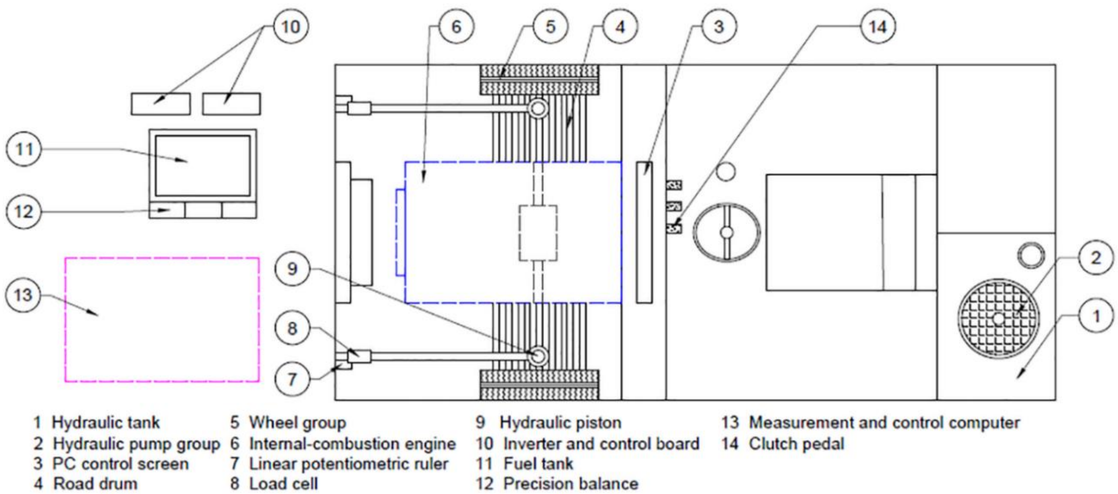


Figure 3. Schematic illustration of vehicle tester

3. Results and Discussion

Figure 4 shows the percentage values of pressing the clutch pedal for different situations of the experimental study. Drivers want a smooth and stable take-off by taking advantage of the sliding effect of the clutch lining between the clutch disk and the flywheel during the engagement. In order to ensure that the vehicle takes off under the desired conditions, it is essential that the engine is at a certain speed and the appropriate gear is selected.

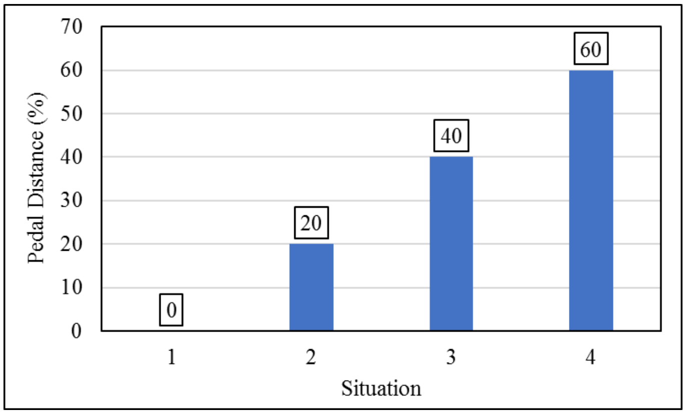


Figure 4. Percentages of pressing the clutch pedal

This study presents the fuel consumption at 3000 1/min in second gear when the clutch pedal was pressed at different distances. Figure 5 shows the fuel consumption values obtained when the clutch pedal is pressed at distances of 0-20-40-60%. The fuel consumption values increased as the pedal pressing distance increased. As the pedal distance increases, fuel consumption rates increase because the accelerator pedal is pressed more for operation at a constant speed of 3000 1/min.

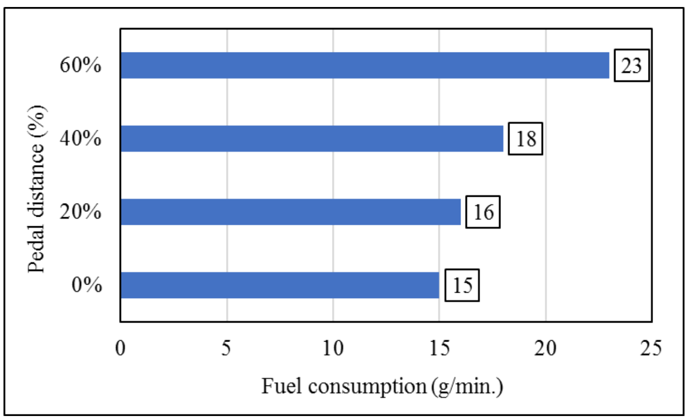


Figure 5. Fuel consumption depending on pedal distance

4. Conclusions

Clutch systems provide transmission, interruption, or partial transmission of the movement obtained from the engine between the engine and the gearbox. The clutch system plays a significant role in vehicle power and torque transmission. The primary purpose is to transmit the motion obtained in the engine to the gearbox differently. Environmental issues are becoming increasingly important, accelerating the studies on fuel consumption. The need for power and torque is high, especially when going uphill and at the first start. In such cases, pressing the clutch pedal may cause differences in vehicle fuel consumption. In this study, the fuel consumption values of a vehicle with a dry clutch lining in second gear at a constant speed of 3000 rpm and 0%, 20%, 40%, and 60% depressions of the clutch pedal were determined using a vehicle tester. Different usage scenarios were created in the experiment by varying the clutch pedal depressing distance. The results showed an increase in fuel consumption values as the clutch pedal travel distance increased. These findings reveal that effective and efficient use of the clutch system is important in controlling fuel consumption.

Conflict of Interest Statement

The authors declare that there is no conflict of interest in the study.

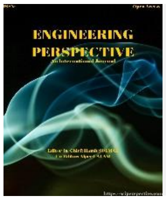
CRediT Author Statement

Hüseyin Bayrakçeken: Conceptualization, Supervision, **Hicri Yavuz:** Conceptualization, Writing-original draft, Validation, **Turan Alp Arslan:** Data curation, Formal analysis

References

1. Fernandes, G.P., Zanotto, P.S., & Sinatora, A. (2015). Contribution on understanding the friction film development in the performance of a dry automotive clutch system. Wear, 342-343, 364-376.
2. Güllü, E., & Kopmaz, O. (2003). Dynamic analysis of a vehicle clutch. Pamukkale University Journal of Engineering Sciences, 9(3) ,357-367.
3. Duque, E.L., Barreto, M.A., & Fleury, A.T. (2012). Use of different friction models on the automotive clutch energy simulation during vehicle launch. ABCM Symposium Series in Mechatronics, Section VIII - Sensors & Actuators, 1376-1389.
4. Virmani, K., Madhogaria, T., & Baskar P. (2021). Design optimization of friction lining of a clutch plate. Materials Today Proceedings, 46(17), 8009-8024.
5. Ost, W., De Baets, P., & Degrieck, J. (2001). The tribological behaviour of paper friction plates for wet clutch application investigated on SAE#II and pin-on-disk test rigs. Wear, 249(5-6), 361-371.
6. Kabacoğlu, S., Pekedis, M., &Yıldız, H. (2021). Theoretical and experimental improvement of the effect of the diaphragm springs form used in the clutch system on the fatigue strength and mechanical characteristics. Uludağ University Journal of the Faculty of Engineering, 26(3), 1121-1138.
7. Ünlüsoy, Y.S., & Akkök, M. (2001). Motorlu taşıtlarda kavrama dinamiğinin incelenmesi. Makina Tasarım ve İmalat Dergisi, 4, 47-55.
8. Park, J., Choi, S., Oh, J., & Eo, J. (2019). Adaptive torque tracking control during slip engagement of a dry clutch in vehicle powertrain. Mechanism and Machine Theory, 134, 249-266.
9. Gatta, A.D., Iannelli, L., Pisaturo, M., Senatore, A., & Vasca, F. (2018). A survey on modeling and engagement control for automotive dry clutch. Mechatronics, 55, 63-75.
10. Pisaturo, M., & Senatore, A. (2016). Simulation of engagement control in automotive dry-clutch and temperature field analysis through finite element model. Applied Thermal Engineering, 93, 958-966.
11. Garrett, T.K., Newton, K., & Steeds, W. (2001). The motor vehicle. 13th ed. Garrett TK, Woburn: Butterworth-Heinemann.
12. Zhao, Z., Lei, D., Chen, J., & Li, H. (2018). Optimal control of mode transition for four-wheel-drive hybrid electric vehicle with dry dual-clutch transmission. Mechanical Systems and Signal Processing, 105, 68-89.
13. Aysal, F.E., Bayrakçeken, H., & Girgin, Z. (2016). The analysis of level increasement at the vehicle gearboxes. Afyon Kocatepe University Journal of Sciences and Engineering, 16, 167-173.
14. Bayrakçeken, H., Yavuz, H., Aysal, F.E., & Türkbay, T. (2020). Comparison of fuel consumption and braking force at different braking pressures in vehicles. Afyon Kocatepe University Journal of Sciences and Engineering. 20, 356-361.

15. Göçer, D.A., & Yıldız, İ. (2023) Optimization of parameters of automated manual transmission in heavy vehicles using K-means algorithm and researching of their effects on fuel consumption. Dokuz Eylul University Faculty of Engineering Journal of Science and Engineering, 25(74), 371-380.
16. Bayrakçeken, H., Aysal F.E., & Mutlu, İ. (2016). The design and manufacturing of brake-suspension test device. Afyon Kocatepe University Journal of Sciences and Engineering, 16, 454-460.
17. Euler-Rolle, N., Mayr, CH., Škrjanc, I., Jakubek, S., & Karer G. (2020). Automated vehicle driveaway with a manual dry clutch on chassis dynamometers: Efficient identification and decoupling control. ISA Transactions, 98, 237-250.
18. Zink, M., & Shead, R. (1998). Clutch and operation as a system. In: 6th LuK Symposium, LuK GmbH, Bühl, Germany, 47-68.



e-ISSN:2757-9077

ENGINEERING PERSPECTIVE

https://sciperspective.com/ Review Paper

Charging Techniques, Infrastructure, and Their Influences

Ahmet Kilic[1]

[1] *Mechatronics Engineering Departmeny, Faculty of Engineering and Architecture, Nisantasi University, Istanbul, 34398, Türkiye*

ABSTRACT

The automotive industry is currently engaged in the biggest transformation of recent years. Electromobility presents a new technological challenge for the automotive industry. In this context, the charging system will play an important key player in the coming years. The requirements for charging systems are very dynamic and diverse from norms, standard and laws as well as from end customers. There is currently no common charging standard for the charging socket worldwide. Worldwide, three charging standards are currently established, which are supported by the European Commission, among others. Here, the individual components and functions charging technologies are systematically described. With this work, the current status for conductive charging technologies and the future trend is summarized. The power consumption of the battery was presented with a measurement result for one charging session.

Keywords: Charging infrastructure, Charging system, Charging technologies, Conductive charging, Electric vehicle

History
Received: 03.08.2023
Accepted: 24.11.2023

Author Contacts
e-mail address: ahmet.kilic@nisantasi.edu.tr

How to cite this paper: Kilic A., (2023). Charging Techniques, Infrastructure, and Their Influences. Engineering Perspective, 3 (4), 68-74. http://dx.doi.org/10.29228/eng.pers.73000

1. Introduction

Due to increasing air emissions and scarcity of fossil fuels, alternative drives such as electromobility are playing an increasingly important role in private motorized transport. As a result, electromobility is becoming increasingly important. Electromobility is based on the development and use of electrically powered and rechargeable vehicles and the move away from traditional vehicle design that uses fossil fuels and oils. Car manufacturers are showing high interest in the future with their new vehicle concepts and new charging technologies. In automotive development, powertrain and vehicle concepts are now changing fundamentally. In compliance with strict new regulations and laws, electromobility is trying to produce more environmentally friendly and efficient vehicles. Electromobility is important drivers for the future of the automotive industry. There are two types of electric vehicles, either all-electric vehicle or hybrid vehicle. A hybrid vehicle has both an electric drive and an internal combustion engine. Hybrid car has either full hybrid or plug-in hybrid. Full hybrid the battery is charged while driving. Plug-in hybrid the battery is charged at the charging station with a charging cable.

There were approximately 25.9 million electric vehicles in 2022, over nine million more vehicles than the previous year. In 2022, 18 million most of the vehicles were battery electric only and 7.9 million of the vehicles were plug-in hybrids. The number of electric cars is increasing worldwide and is expected to be about 226 million new electric cars by 2030 according to the International Energy Agency (IEA) [1]. Among them, most of the vehicles are expected to be exclusively battery electric, with around 180 million, and about 46 million of the cars will be plug-in hybrids, Figure 1 In Germany alone, The Federal Government has set a target of 15 million electric vehicles by 2030 and has been promoting them with the environmental bonus since September 2023.

The charging infrastructure plays a significant role in the future of electromobility development. Successful electromobility development depends on the technical and political supports. For the technical support of electromobility development, the optimization and further development of the HV battery with ranges, charging infrastructure with convenience and power grid with secure energy supply play a significant role. An important point is the competitiveness of electric vehicles, as the costs without subsidies are too high compared to a normal combustion engine. are too high compared to the normal combustion engine. The additional costs are due to the Batteries and their production [2]. As a result, manufacturers are under high-cost pressure to make the vehicles attractive for the market.

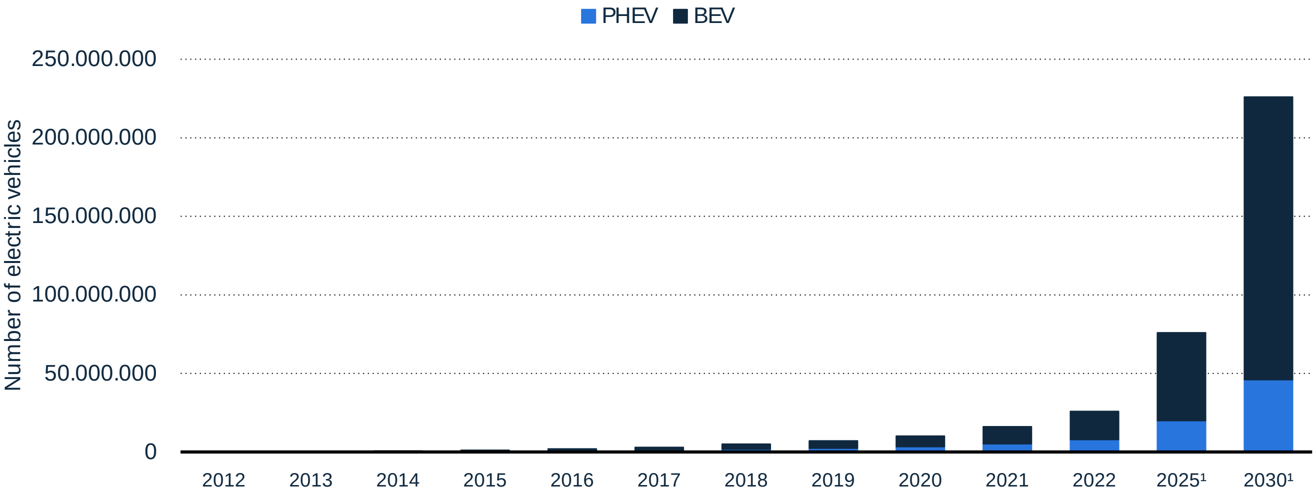


Figure 1. Number of electric vehicles worldwide from 2012 to 2022 and forecast to 2030 [1]

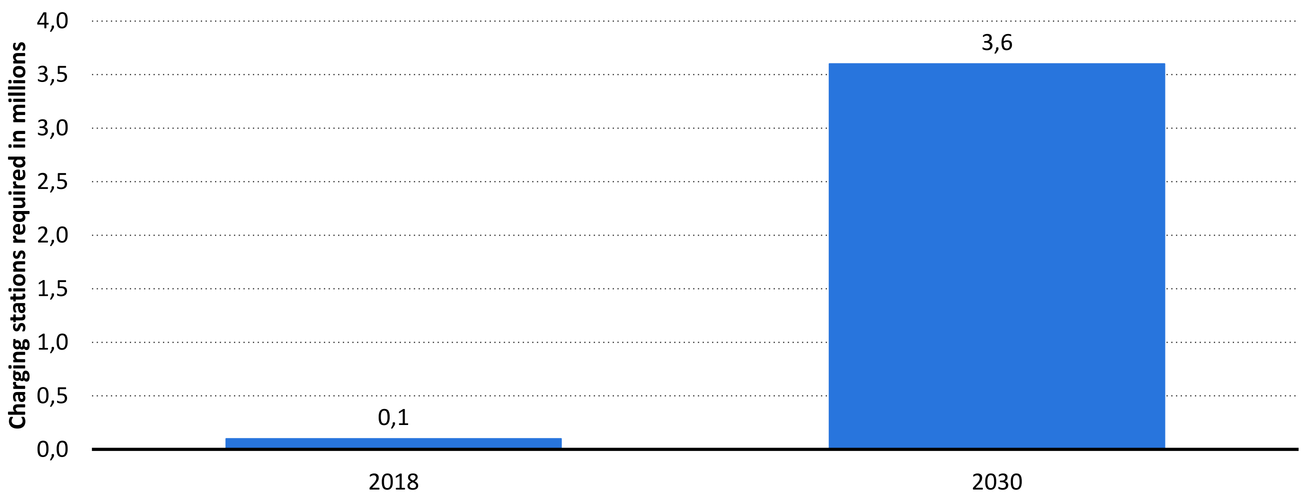


Figure 2. Prognosis for relevant charging stations in European Union countries [4]

In 2018, there were about 0,1 million charging stations in Europe, Figure 2. As the number of newly registered electric vehicles increases, the demand for relevant charging stations increases sharply [3]. Sufficient charging stations for electric vehicles need to be newly built. In Europe, about 3.6 million public charging stations will be needed by 2030 [4]. Thus, the demand of the electric vehicle can be compensated. In Germany in 2022, according to the Federal Network Agency, there were about 70,000 e-charging stations. The aim is to reach one million by 2030.

Improving customer acceptance for charging electric vehicles are essential secure and convenient charging process e.g., plug and charge, shorter charging times with sufficient power, sufficient available charging stations and high battery ranges.

The charging technologies are very dynamic [5]. There are always new requirements. With this work, current status and future for charging infrastructure parameters and their influences as well as conductive charging systems are considered and evaluated in Section 2. In section 3, the charging process and charging power from measurements are presented. In section 4 the results are summarized.

2. Charging Infrastructure Parameters and Their Influences

2.1 Electric vehicle

The main components in the electric vehicles are [5,6], Figure 3:

- High voltage battery
- Low voltage battery
- eAxle with electric motor
- Power electronics
- Charging converter
- Vehicle control unit

Energy is stored in the form of current in the high-voltage battery. The battery must be charged each time and its capacity determines the range of the vehicle. Electrical energy from the current stored in the high-voltage battery is converted by the electric motor into mechanical power by generating magnetic fields. These magnetic fields generate attractive and repulsive forces - and electric vehicles start driving.

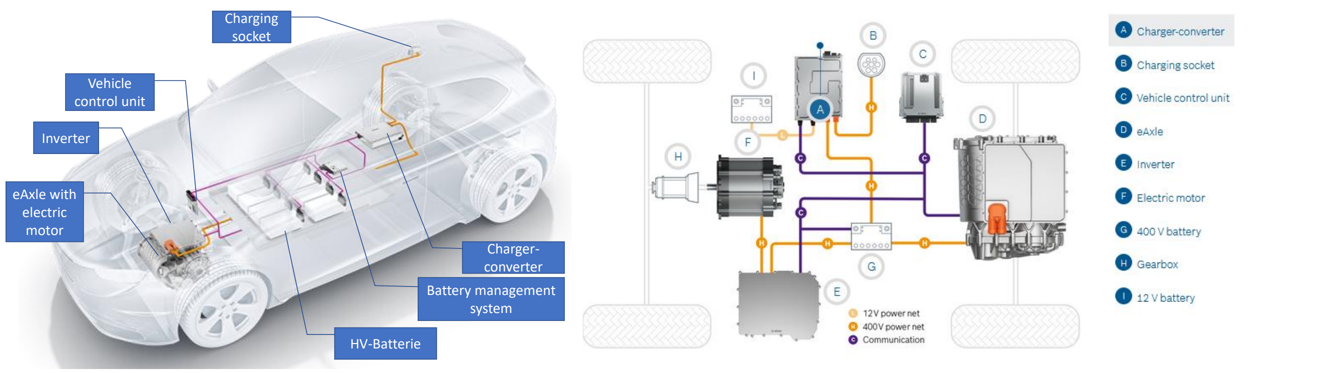


Figure 3. System overview electric vehicle [6]

2.2 Charging technologies

There are different systems for charging the HV battery [7-9], Figure 4. With this work conductive charging systems are considered. Conductive charging is done with the help of a cable and plug connection between the vehicle and the power grid [10].

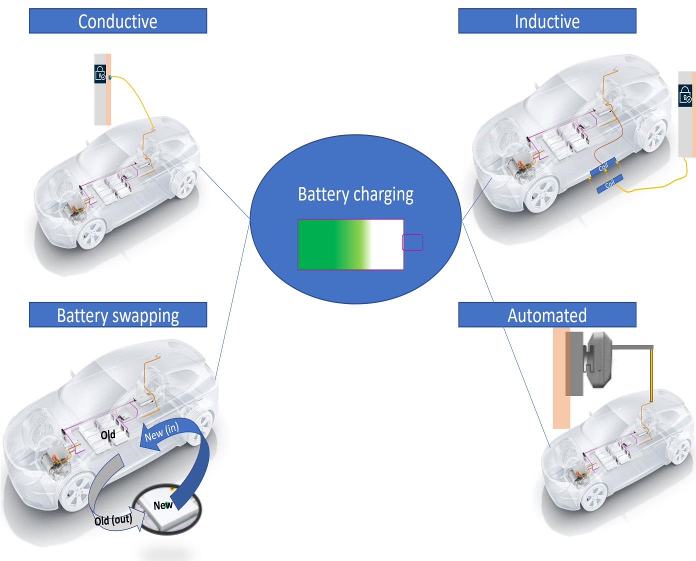


Figure 4. Charging systems for charging the high voltage battery

Charging the HV battery [11] with conductive system allows using the direct current (DC) or alternating current (AC) charging technologies. DC charging transports the direct current from DC charging stations directly to the battery. AC charging transports the alternating current from charging stations to the on-board charger (OBC). OBC converts alternating current to direct current and transports it to the battery in the vehicle, Figure 5.

2.3 Charging modes

There are different international norms and standards (ISO, IEC, DIN, DKE, SAE) for electric vehicles and charging systems. These norms and standards determine the plug types, charging modes, sockets, charging control, safety. The charging modes are defined according to international standard IEC 61851-1 [12]. There are four charging modes for electric vehicles. This charging mode describes the communication between vehicle and charging stations, safety, current and voltage limit, type of cable connection between vehicle and charging stations, type of charging technologies (AC or DC), Figure 6.

Charging mode 1-3 describes AC charging with a standardized plug-in device. Charging mode 4 describes DC charging at a permanently installed charging station. Due to the high safety requirements, the charger is not located in the vehicle but is part of the charging station. The charging line is also permanently connected to the charging station. In Mode 4, the vehicle can be charged using two different plug-in systems. The "Combined Charging System" (CCS) with a charging current of up to 200 A and a charging power of up to 170 kW and the CHAdeMO system originating from Japan with a lower charging power.

2.4 Charging plug types

The communication and energy transfer between charging station and vehicle was done with charging plug in conductive charging. The plug types for electric vehicles is summarized with international standard IEC 62196 and is maintained by the International Electrotechnical Commission (IEC). According to the standard, the plug types must be adapted between the vehicle and the charging stations. There are currently different plug types worldwide. The plug types are based on the regions, current type (AC or DC), maximum power (current and voltage), Figure 7. A high charging power leads to a faster charging of the battery.

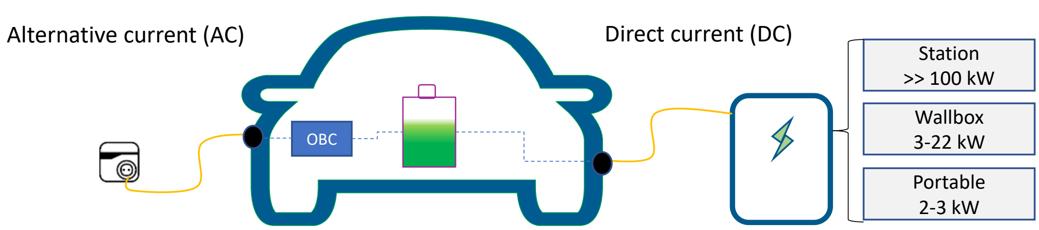


Figure 5. Conductive charging technologies for charging the HV battery

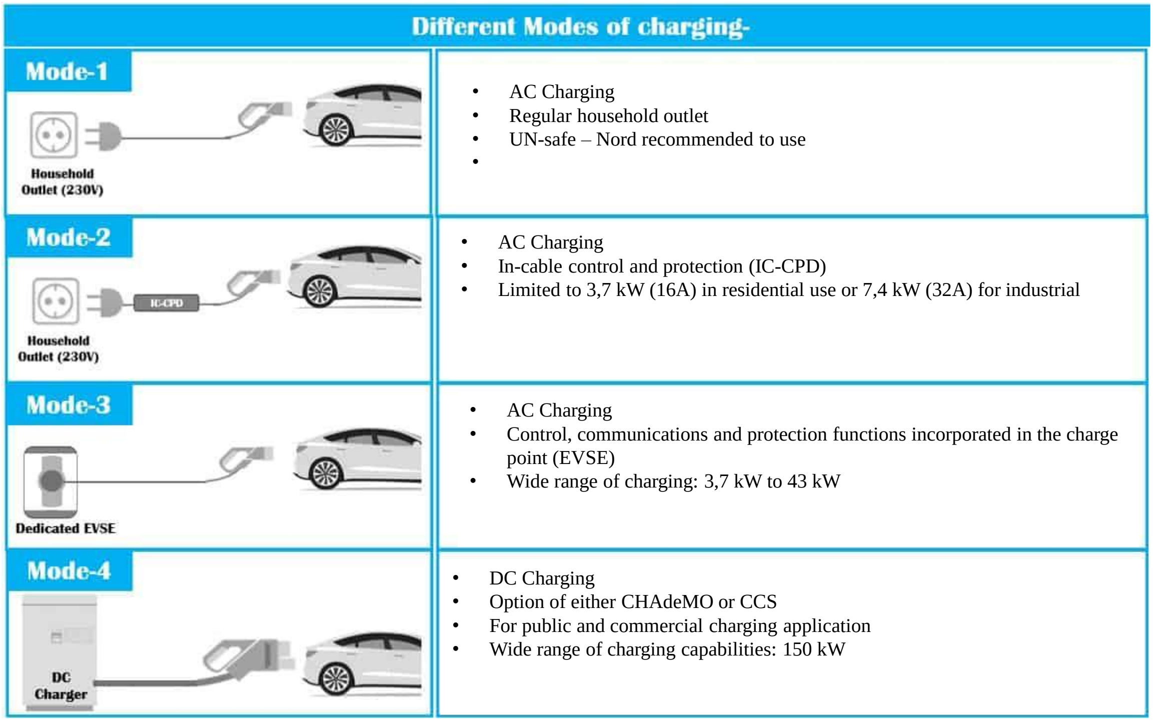


Figure 6. Modes of charging [14]

Combined Charging System (CCS):

Combined Charging System describes a combined fast charging system and is an international charging standard according to IEC 62196 [15]. The plug variants are Combo-2 (Type 2) for EU and Combo-1 (Type 1) for NA standardized. The standardized CCS connector system can be used to implement both DC and AC charging methods [16]. The plug is divided into 2 sections. The upper part corresponds to the Type2 connector, which is used in the DC area only for communication between the vehicle and the charging pole. The lower part is used for DC charging. Thus, the CSS connector in the vehicle offers the possibility to use both DC and AC cables. With the CCS connector, charging can be done via direct current with a power of max. 350 kW and voltage 400 V (up to 950 V). The charging power is strongly dependent on the battery charge level and temperature.

CHAdeMO plug:

The CHAdeMO plug describes a Japanese fast charging plug for charging with direct current (DC) up to 400 kW power (CHAdeMO 2.0).

Type 1 plug:

Type 1 plug describes a single-phase plug with its maximum charging power at 7.4 kW (230 V, 32 A) and is an international charging standard standardized according to SAE J1772 as well as used inn North America and Asia.

Type 2 plug:

Type 2 plug describes a three-phase plug with its maximum charging power at 43.5 kW (4000 V, 63 A) and is an international charging standard standardized according to IEC 62196-1 and used in Europe.

GB/T plug:

The CHAdeMO plug describes a Chinese fast charging plug according to 20234- GB/T standard for charging with alternating and direct current. There are two variants of GB/T plugs: one for AC charging and one for DC fast charging. The GB/T AC charging plug is single-phase and delivers up to 7.4 kW. It does look the same as the Type 2 plug.

Tesla plug:

Tesla connector describes AC and DC charging capabilities according to NACS standard with AC connector 240V, 48A and with CD connector 1000V, 400A. NACS stands for the North American Charging Standard and is the proprietary charging plug used by Tesla vehicles in North America. It has been adopted by several automakers, including Ford, GM, Rivian and Lucid, signaling a shift away from CCS in North America.

ChaoJi plug:

There are different charging technologies currently in the market for charging the electric vehicle. The requirements are to develop a uniform, international, faster and safer charging technologies. For this, there are different development activities worldwide. Japan and China agreed to jointly develop a next generation charging technology. This is referred to as "ChaoJi." It has the potential to become a global standard with power up to 900 kW [18]. In addition, it is also much more compact. Due to the high charging power, electric vehicles are charged within a very short time. Even very large batteries of electric trucks can thus be charged faster with the ChaoJi connection.

Megawatt Charging System (MCS):

Megawatt Charging System describes a fast-charging system for mainly trucks with a power 4.5 MW (max charging current 3000 A, 1.5 kV) and further development of CCS. MCS technology is currently in the development phase with international partners and standardization committees [20,21].

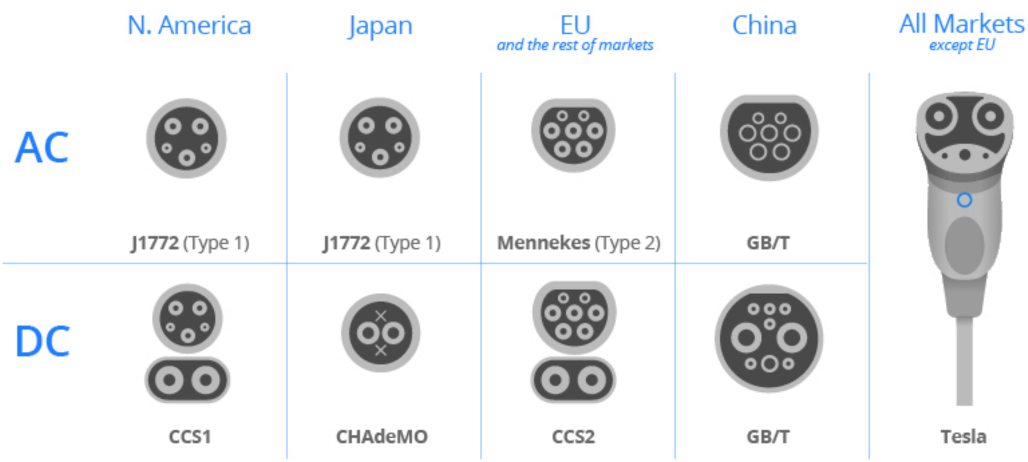


Figure 7. Types of electric vehicle chargers [17]

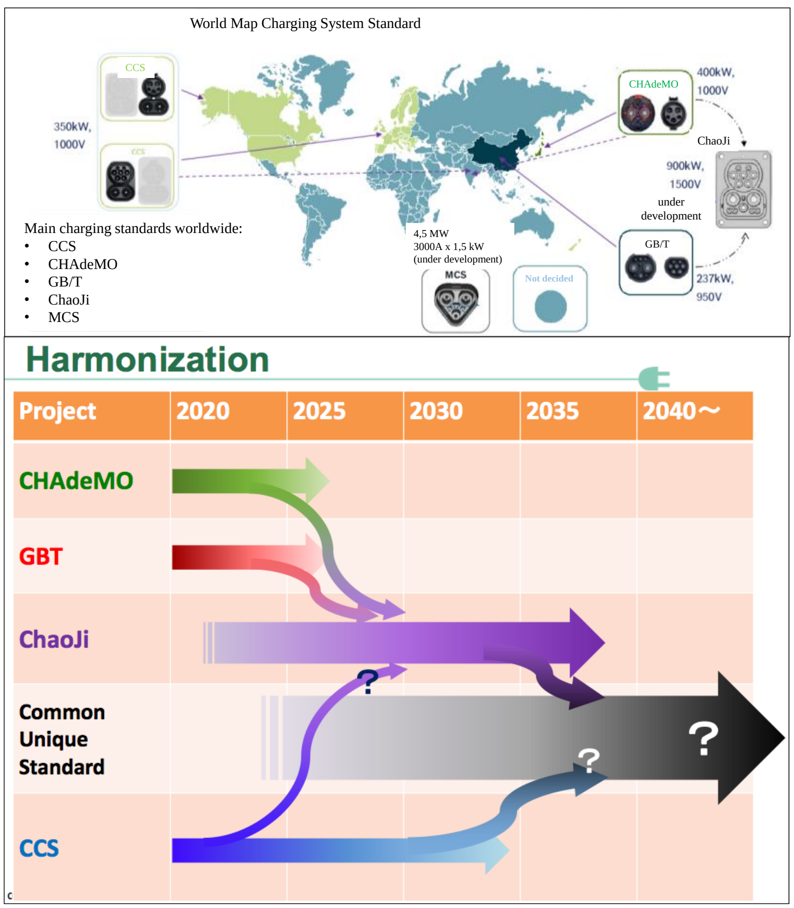


Figure 8. Trend for charging technologies [18,19]

3. Charging Process and Charging Capacity

3.1 Charging process

Cable is plugged into vehicle. The lines marked PP and CP correspond to the plug detection (PP) and the pilot line (CP). The existing CP and PE (ground) lines are used for high-level communication [22,23]. The connection to the control units of the EVSE and the vehicle is made via one PLC modem each. Charging process must be prepared: First, the charging cable is connected, insulation test is performed, voltage to the battery is regulated, then first pre contactors are closed. Before the energy transfer from charging station to electric vehicles is started, the relevant current and voltage limit and demand must be sent from vehicle (battery) to charging station. The current and voltage demand of the battery is sent from vehicle to charging station. Charging station provides this requested power demand to vehicle. Then the main contractor in the charging station is closed. Thus, the energy transfer to vehicle started until the HV battery is charged, Figure 9.

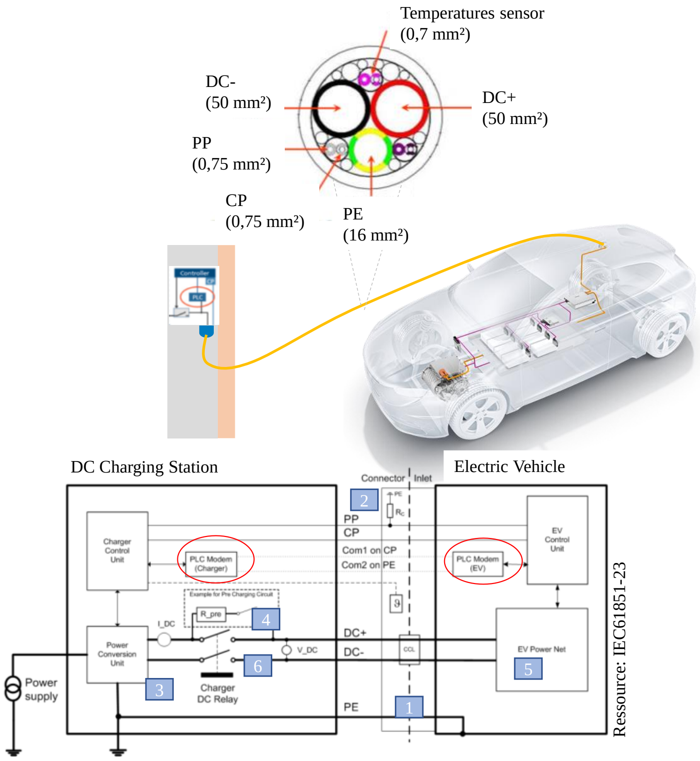


Figure 9. Charging process and architecture for DC charging

3.2 Charging capacity

One of the important requirements for charging a battery is the duration of the charging process. The duration depends on the charging power of the vehicle and the charging station. The trend is towards the shortest possible charging time for a charging process. Increasing the charging power of the vehicle and the charging station can lead to faster charging of the electric vehicle (battery), Figure 10. The charging power is determined by the amperage, voltage and number of phases. Household appliances usually use only one phase, but electric vehicles can also be charged in three phases. In this way, double or triple the power reaches the vehicle - while the amperage remains the same. With a three-phase connection, the way in which the charging station is connected to the grid also plays a role. Depending on whether it is connected in a star or delta connection, the voltage is 230 or 400 volts.

Enclosed is the charging capacity (single-phase alternating current):

•Charging capacity (3.7 kW) = phases (1) * voltage (230 V) * amperage (16 A)

Charging capacity (three-phase, three-phase alternating current), star connection:

•Charging capacity (22 kW) = phases (3) * voltage (230 V) * amperage (32 A)

After the contactors of charging station and battery are closed, the energy transfer from charging station to HV battery is started. Thus, the battery voltage increases, Figure 11. To avoid damage of HV battery, the charging process of the battery is set at constant charging current. This also prevents the battery from aging faster. The voltage of the battery is regulated at constant battery current until the SOC reaches 80%. SOC state from 80% to 100%, the battery current is reduced at constant the voltage of the battery.

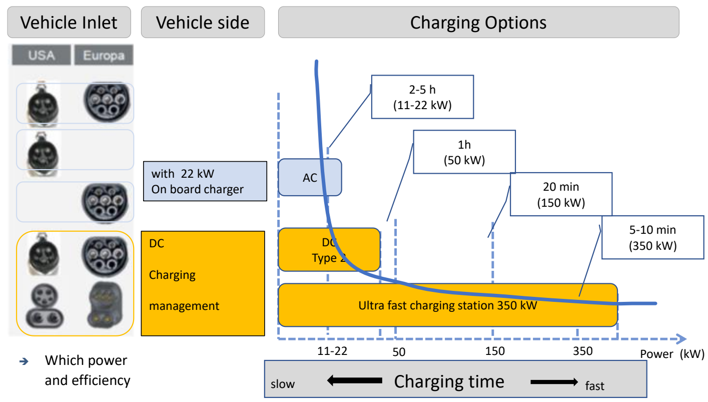


Figure 10. Relationship between charging capacity-charging duration

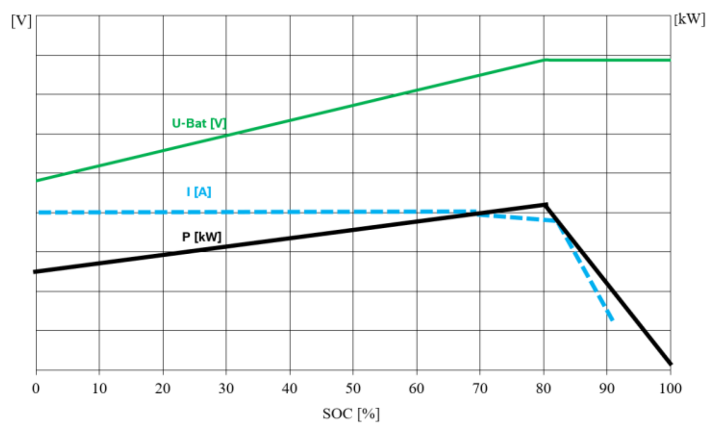


Figure 11. Battery charging power for one charging process

4. Conclusions

The charging infrastructure is the important key player for electric mobility. Here, the current status for electric vehicle and charging stations and for the future prognosis worldwide is presented. Demand of relevant charging stations have increased drastically.

With this work, the latest trend and charging technologies regarding charging plug ChaoJi and Megawatt Charging System plug, and their roadmap are presented.

The requirements for charging power and charging time are presented. The goal is to charge HV battery within the shortest time. There is trend towards ultra-fast DC charging with 350 kW charging power.

Here the regulation of charging power was interpreted with a measurement result first by voltage and then by current and the power consumption of the battery was evaluated for one charging process with measurement result.

Nomenclature

AC	Alternating Current
BEV(s)	Battery Electric Vehicle(s)
BMS	Battery Management System
CC	Constant Current
CCS	Combined Charging System
CHAdeMO	CHArge de MOve
DC	Direct Current
EV(s)	Electric Vehicle(s)
EVSE(s)	Electric Vehicle Supply Equipment(s)
GB/T	Guo Biao/Tu¯ıjiàn (Recommended)
HPC	High Power Charging
HEV	Hybrid Electric Vehicle(s)
I	Battery current
IEA	Internationalen Energieagentur
IEC	International Electrotechnical Commission
MCS	Megawatt Charging System Stecker
OBC	On-Board-Charger
P	Charging capacity (power)
PHEV	Plug-in Hybrid Electric Vehicle
SOC	State of Charge
SoH	State of Health
U-Bat	Battery Current

Conflict of Interest Statement

The author declare that there is no conflict of interest in the study.

References

1. Internationalen Energieagentur (IEA): Anzahl von Elektroautos weltweit von 2012 bis 2022 und Prognose bis 2030. https://de.statista.com/statistik/daten/studie/168350/umfrage/bestandsentwicklung-von-elektrofahrzeugen/ (accessed on 12 July 2023).
2. Hofmann, P. (2023). Energiespeicher für hybridfahrzeuge. Hybridfahrzeuge: Grundlagen, komponenten, fahrzeugbeispiele. Berlin, Heidelberg: Springer Berlin Heidelberg, 293-360.
3. Mastoi, M.S., Zhuang, S., Munir, H.M., Haris, M., Hassan, M., Usman, M., Bukhari, S.S.H., & Ro, J.S. (2022). An in-depth analysis of electric vehicle charging station infrastructure, policy implications, and future trends. Energy Reports, 8, 11504-11529.
4. Internationalen Energieagentur (IEA): Prognose der benötigten öffentlichen Ladestationen für Elektrofahrzeuge in den Ländern der Europäischen Union in den Jahren 2018 und 2030. https://de.statista.com/statistik/daten/studie/1036435/umfrage/prognose-der-benoetigten-oeffentlichen-ladestationen-fuer-elektroautos-in-der-eu/. (accessed on 12 July 2023).
5. Abid, M., Tabaa, M., Chakir, A., & Hachimi, H. (2022). Routing and charging of electric vehicles: Literature review. Energy Reports, 8, 556-578.
6. Decker, K.H., & Kabus, K. (2022). Kraftfahrtechnisches taschenbuch. Springer Vieweg Wiesbaden.
7. Ahmad, A., Khan, Z.A., Alam, M.S., & Khaateb, S. (2018). A review of the electric vehicle charging techniques, standards, progression and evolution of EV technologies in Germany. Smart Sciences, 6, 36-53.
8. LaMonaca, S., & Ryan, L. (2022). The state of play in electric vehicle charging services–A review of infrastructure provision, players, and policies. Renewable and Sustainable Energy Reviews, 154, 111733.
9. Kilic, A. (2016). Device and method for electrically connecting a charging station with a charging socket of a vehicle. Patent DE102014226755A1
10. Kilic, A., & Henkel, A. (2016). Vehicle socket and cooperating plug. Patent DE102015211997 A1.
11. Kilic, A. (2023). High-voltage battery, the method for running high-voltage battery, battery system and vehicle. Patent CN107650684A.
12. BS EN IEC 61558-1:2019. (2019). Safety of power transformers, power supplies, reactors and similar products – Part 1: General requirements and tests.
13. IEC 62196-1:2022. (2022). Plugs, socket-outlets, vehicle connectors and vehicle inlets-Conductive charging of electric vehicles.
14. Wang, K. Electric vehicle charging levels, modes and types explained, North America vs. Europe charging cables and plug types.
15. IEC 62196-1:2022. (2022). Plugs, socket-outlets, vehicle connectors and vehicle inlets-Conductive charging of electric vehicles.
16. Köhler, S., Baker, R., Strohmeier, M., & Martinovic, I. (2022). End-to-end wireless disruption of CCS EV charging. Proceedings ot he 2022 ACM SIGSAC Conference on Computer and Communications Security, 3515-3517.
17. Raff, R., Golub, V., Pelin, D., & Topić, D. (2019). Overview of charging modes and connectors for the electric vehicles. 2019 7th International Youth Conference on Energy (IYCE), 1-6.
18. Rachid, A., Fadil, H.E., Gaouzi, K., Rachid, K., Lassioui, A., Idrissi, Z.E., & Koundi, M. (2023). Electric vehicle charging systems: Comprehensive review. 16, 255.
19. Mastoi, M.S., Zhuang, S., Munir, H.M., Haris, M., Hassan, M., Usman, M., Bukhari, S.S.H., & Ro, J.S. (2022). An in-depth analysis of electric vehicle charging station infrastructure, policy implications, and future trends. Energy Reports, 8, 11504-11529.
20. Maske, P., Chel, A., Gopal, P.K., & Kaushik, G. (2021). Sustainable perspective of electric vehicles and its future prospects. JSMPM, 1, 17-32.
21. Schneider, J., Teichert, O., Zahringer, M., Balke, G, & Lienkamp, M. (2023). The novel Megawatt Charging System standard: Impact on battery size and cell requirements for battery-electric long-haul trucks. eTransportation, 17, 100253.
22. Kilic, A. (2023). Analysis of charging systems for electric vehicle. International Journal of Smart Grid, 7, 177-186.
23. Kilic, A. (2023). Plug and charge solutions with vehicle-to-grid communication. Electric Power and Component Systems, 51, 1786-1814.